Reduction in Vehicle Emissions Attributable to Alternative Transportation Fuels and its Prospective Impact on Air Quality and Public Health

Timothy C. Coburn, Kenneth J. Kelly, and Brent K. Bailey

National Renewable Energy Laboratory
Golden, Colorado

TEST PROGRAM

- Statistically-designed study
- Federal fleet & local transit agencies
- Multiple testing labs
- Multiple makes/models of vehicles
- Vehicles from multiple sites throughout U.S.
- EPA test procedures
- In-use emissions
- Tests repeated at various mileage levels
- Target fuels: Ethanol, Methanol, Compressed Natural Gas
- Most extensive study of its kind

Situation

- The U.S. Department of Energy (DOE) is heavily promoting development and deployment of alternative fuels and alternative fuel vehicles (AFVs) to:
  - Reduce dependence on imported oil
  - Improve air quality
- On behalf of DOE, the National Renewable Energy Lab (NREL) has undertaken an extensive evaluation of AFVs, including emissions performance.
- This presentation summarizes the emissions results and public health implications of this study

Public Health Considerations

- Automotive emissions are suspected to contribute to and/or cause a number human health disorders
- Human studies not yet conclusive; results of animal studies more compelling
- AFV's are expected to exhibit lower levels of exhaust emissions relative to conventionally-fueled vehicles
- The DOE policy has the potential to substantially alter air quality and to positively impact other public health scenarios

Hypothesis

- If AFVs have improved overall emissions profiles,
- Then emissions-induced risk of disease and health disorders should be commensurately reduced,
- Particularly in communities having larger concentrations of such vehicles.
- Lower risk should translate to:
  - reduced costs of medical care
  - reduced insurance premiums
  - generally more favorable business climate

EPA Standards: (Tier 1; g/mi)

Vehicle Type	Carbon Monoxide	Oxides of Nitrogen	Hydrocarbons*
Sedans	3.4	.4	.25
Vans	5	1.1	.39
Transit Buses	N/A	N/A	N/A

* For gasoline and CNG, non-methane hydrocarbons; for ethanol and methanol, organic matter non-methane hydrocarbon equivalents

Vehicles in Program

Make/Model	Conventional	Alternative Fuel
Dodge Spirit	70	71
Chevy Lumina	22	22
Ford Econoline Van	18	16
Dodge B250 Van	38	37
Transit Buses (DDC Engines)	17	20
Transit Buses (Cummins Engines)	14	21
Line Haul Trucks	1	4
Snow Plows	1	2
Garbage Packers	3	6
Total	**184**	**199**

Findings

Sedans & Light-Duty Vans

- Most AFVs have uniformly lower exhaust emissions, with the levels of CO, NO_X, and HC well below EPA standards
- For toxic constituents, AFVs have:
  - lower alcohols
  - mixed results for aldehydes (as expected), depending on the fuel
- For ozone-forming potential, AFVs have generally lower levels

Transit Buses

- AFVs have lower PM and NO_X, but results for other constituents are mixed

Heavy-Duty Vehicles

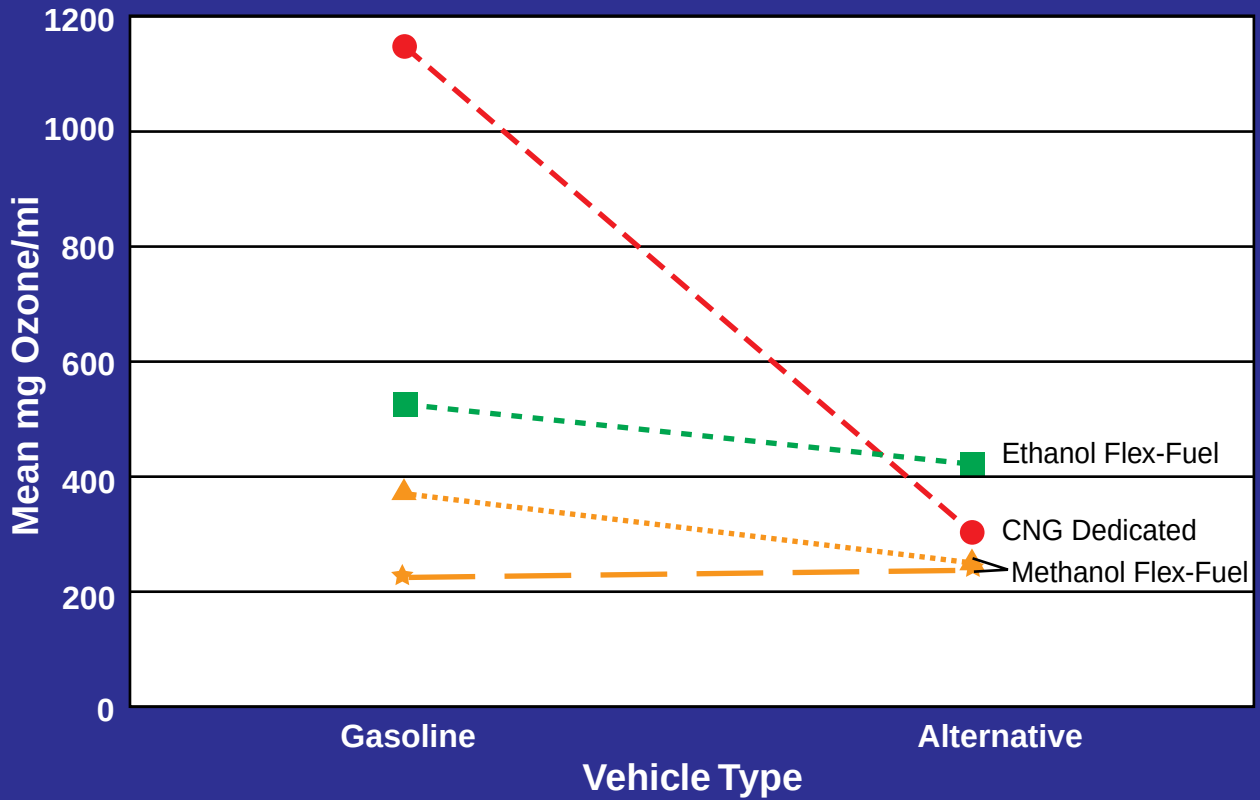
- AFVs have lower PM

Experimental Results

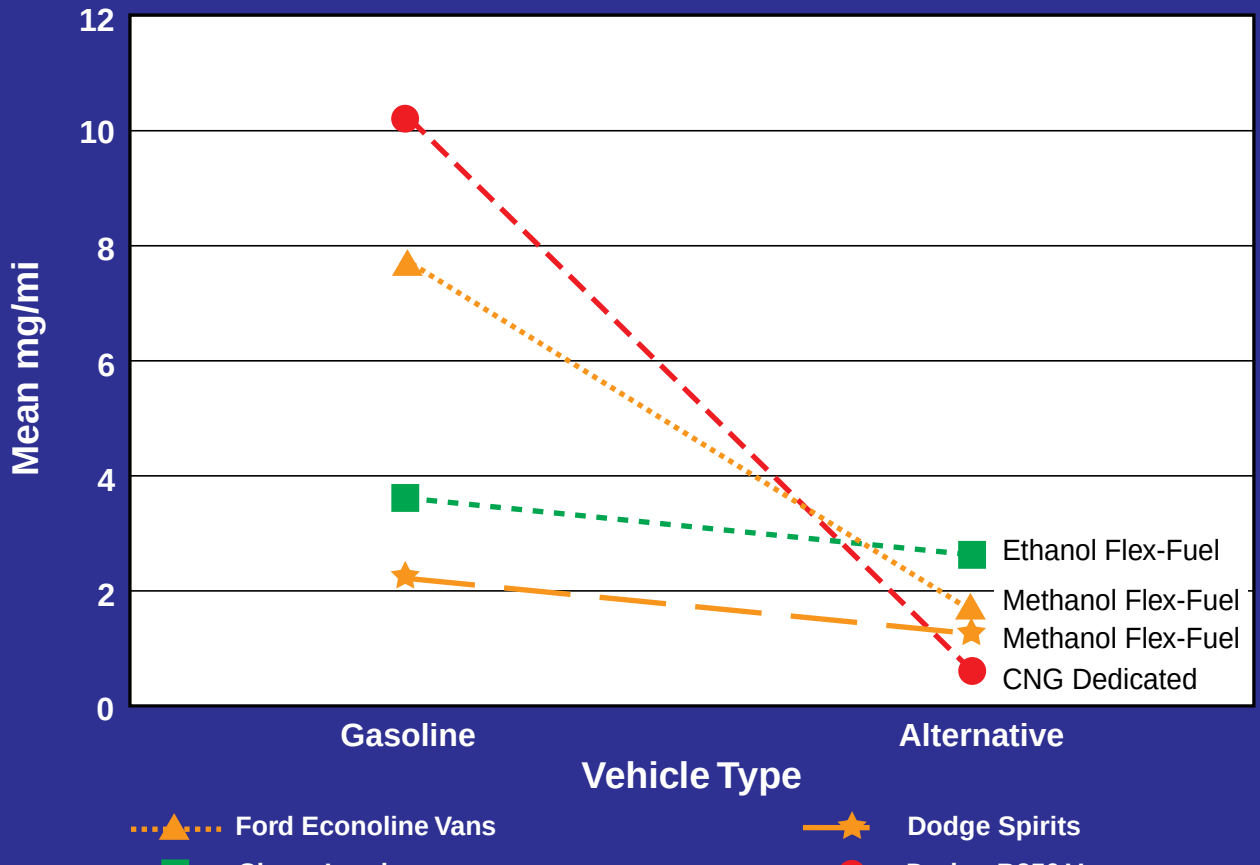
Toxics and Ozone Precursors:

Sedans and Light-Duty Service Vans (19 AFVs; 12 Controls)

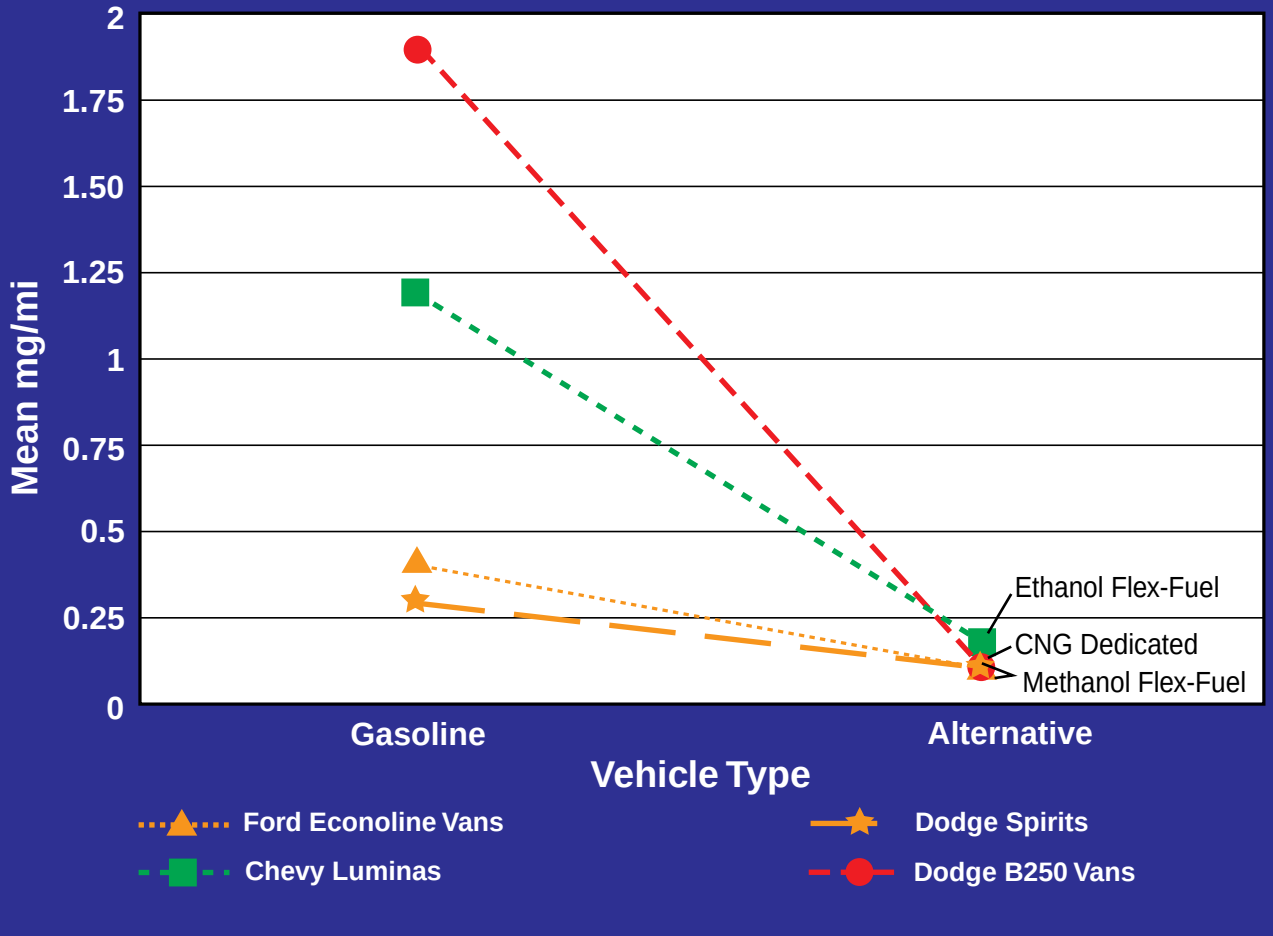
Ozone-Forming Potential (OFP)



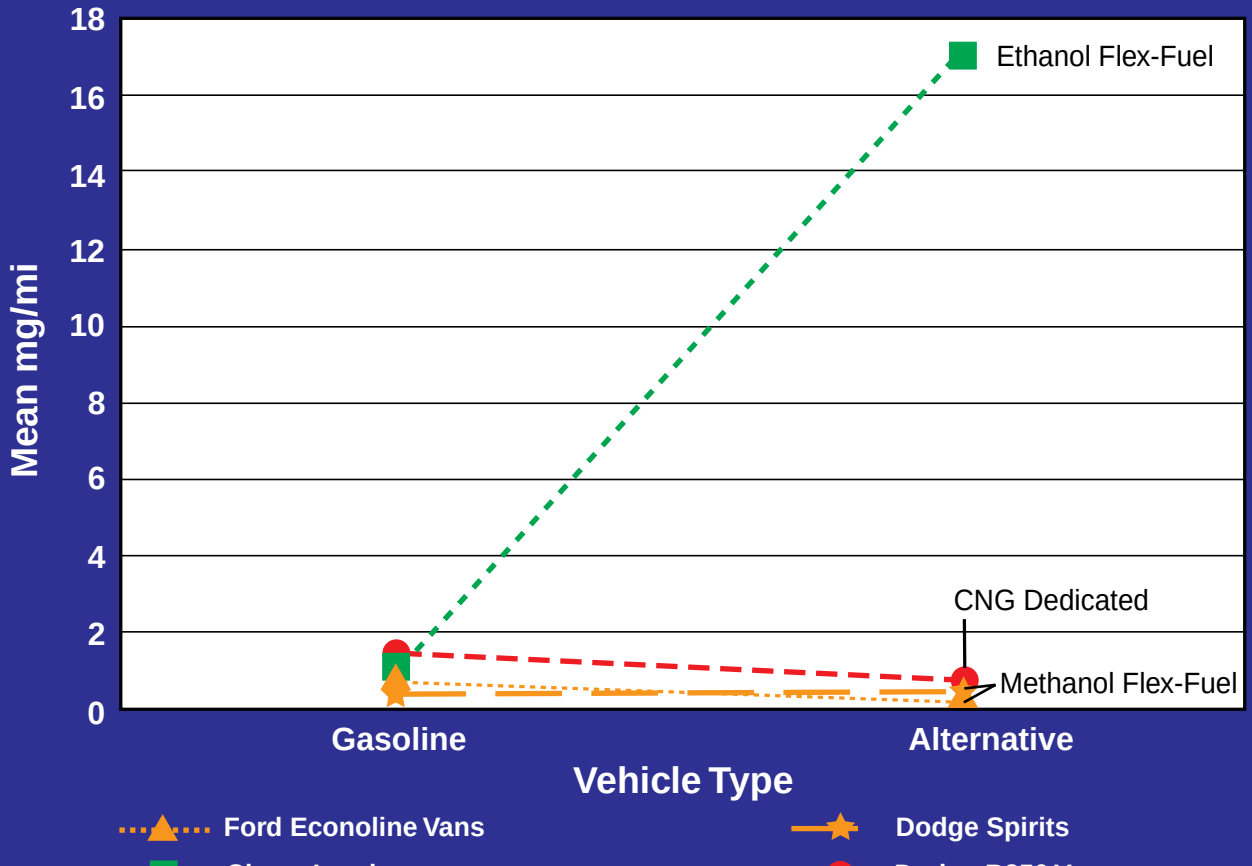
Benzene (C_6H_6)



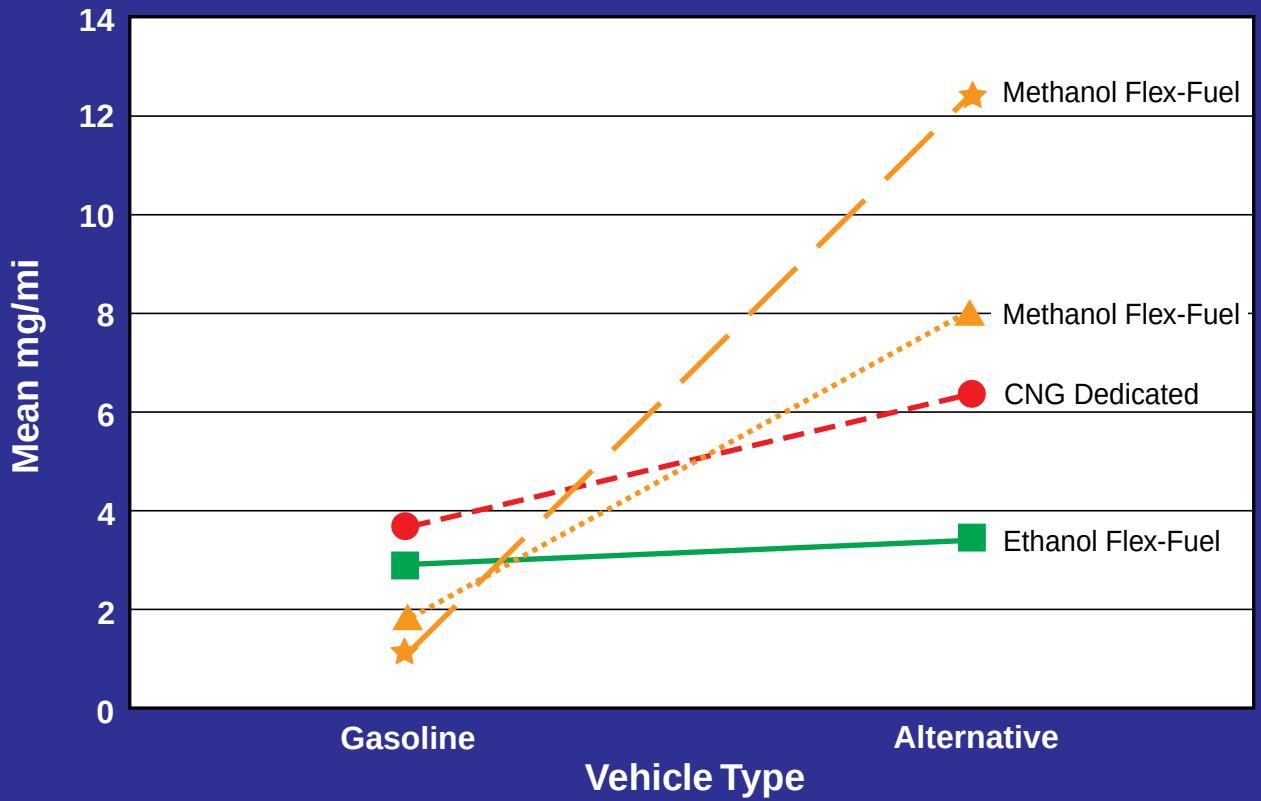
1,3-Butadiene



Acetaldehyde (CH_3CHO)



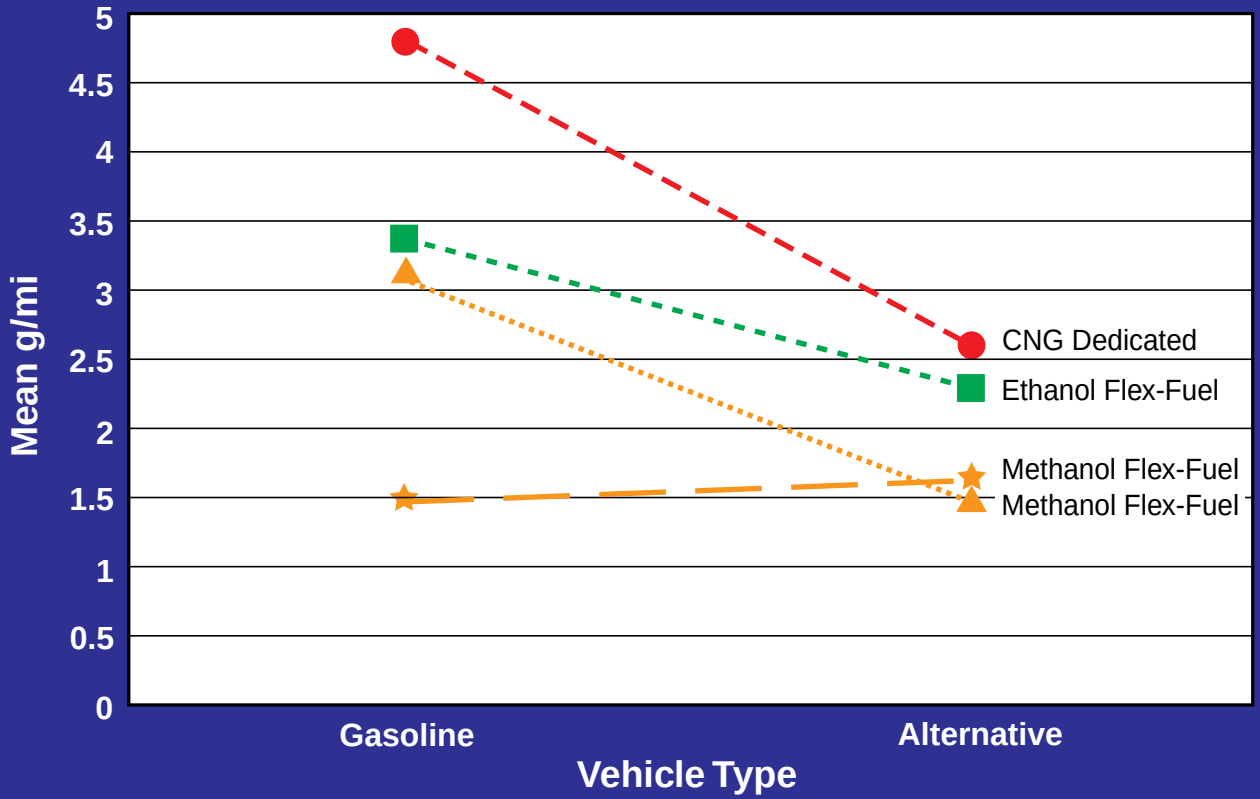
Formaldehyde (HCHO)



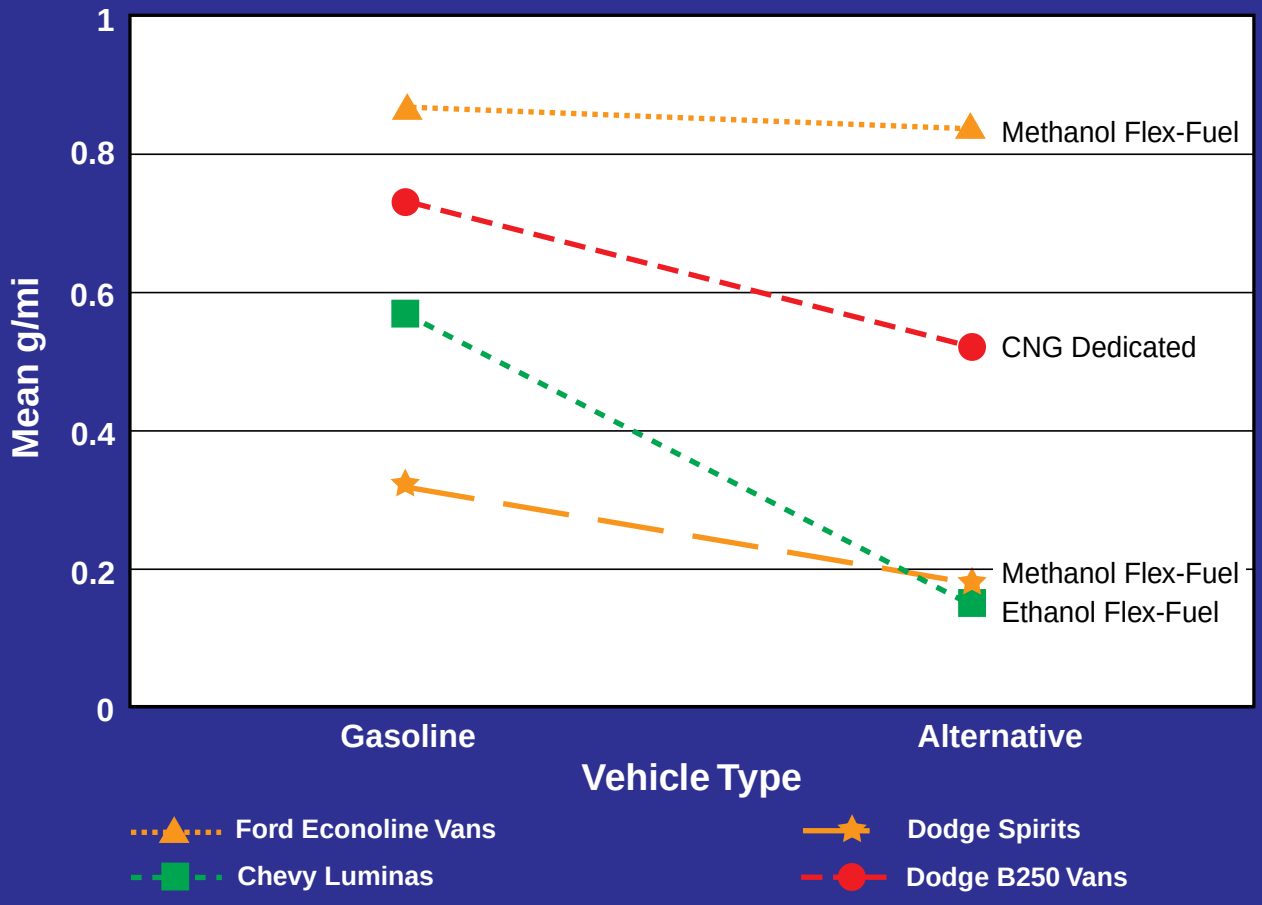
Regulated Emissions:

Sedans and Light-Duty Service Vans (146 AFVs; 148 Controls)

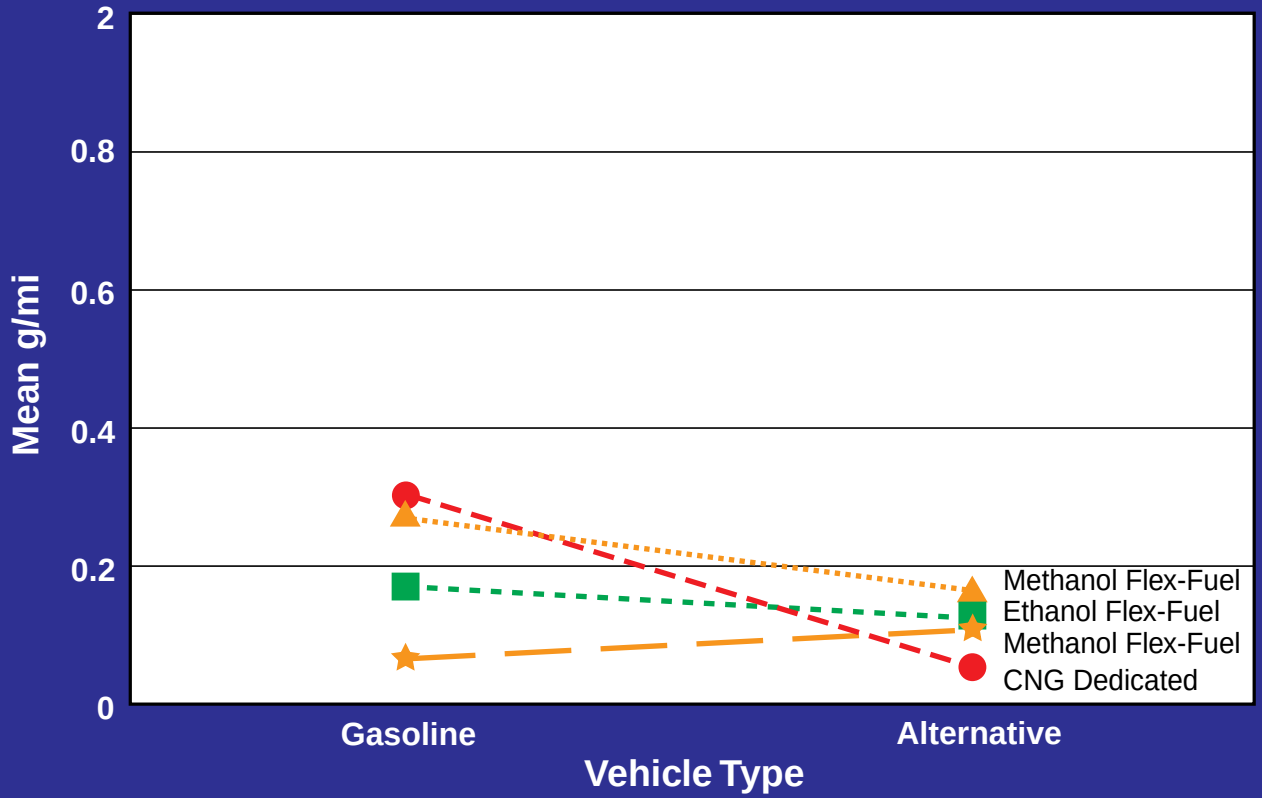
Carbon Monoxide (CO)



Oxides of Nitrogen (NO_X)



Hydrocarbons*



Ford Econoline Vans

Chevy Luminas

Dodge Spirits

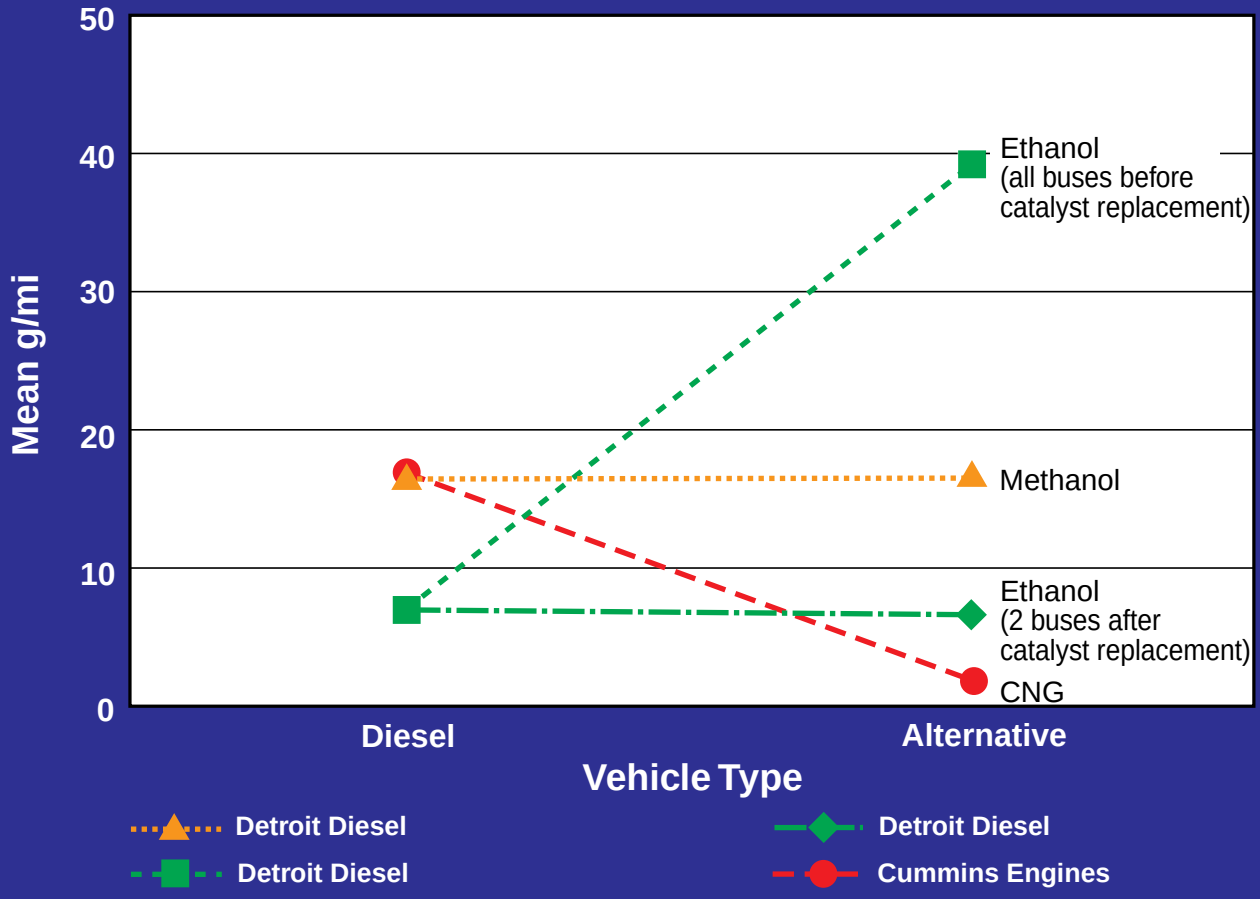
Dodge B250 Vans

(*CNG = Non-Methane Hydrocarbons; Ethanol & Methonal = Organic Matter Non-Methane Hydrocarbons

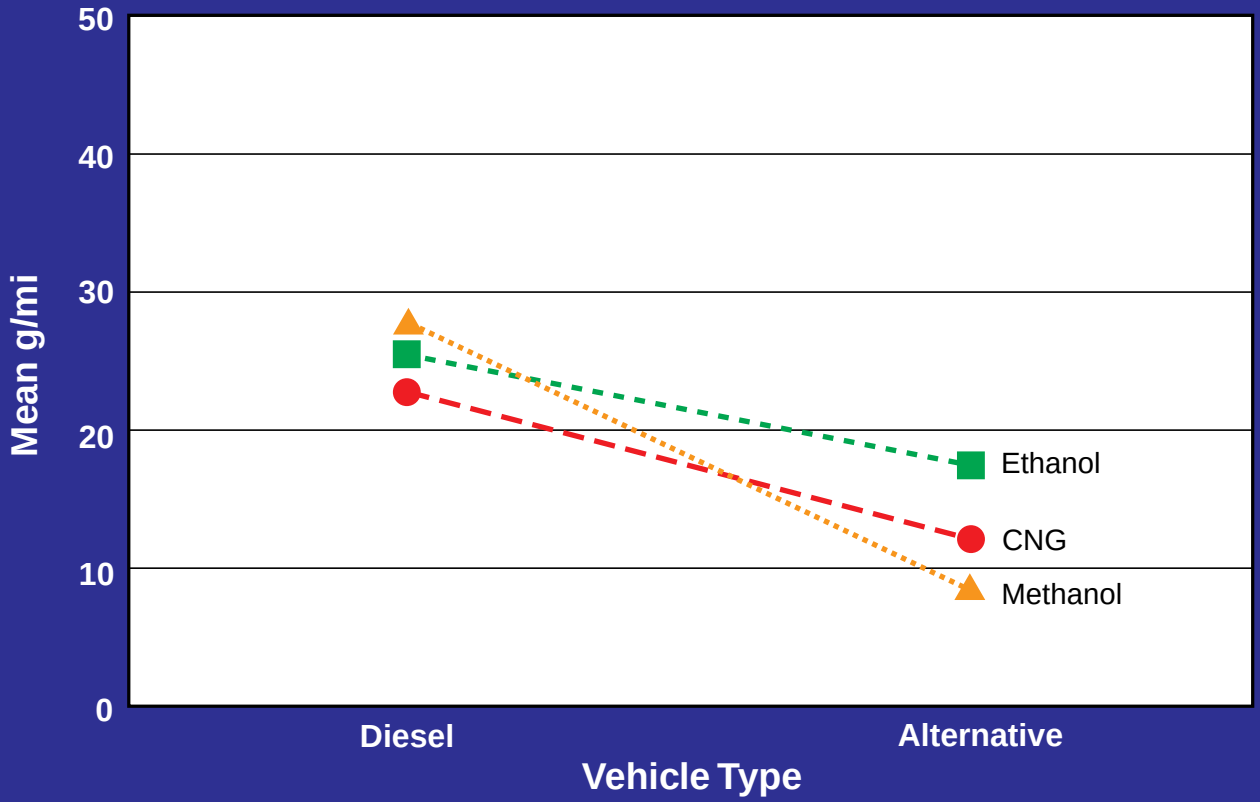
Regulated Emissions:

Transit Buses (41 AFVs; 31 Controls)

Carbon Monoxide (CO)



Oxides of Nitrogen (NO_X)

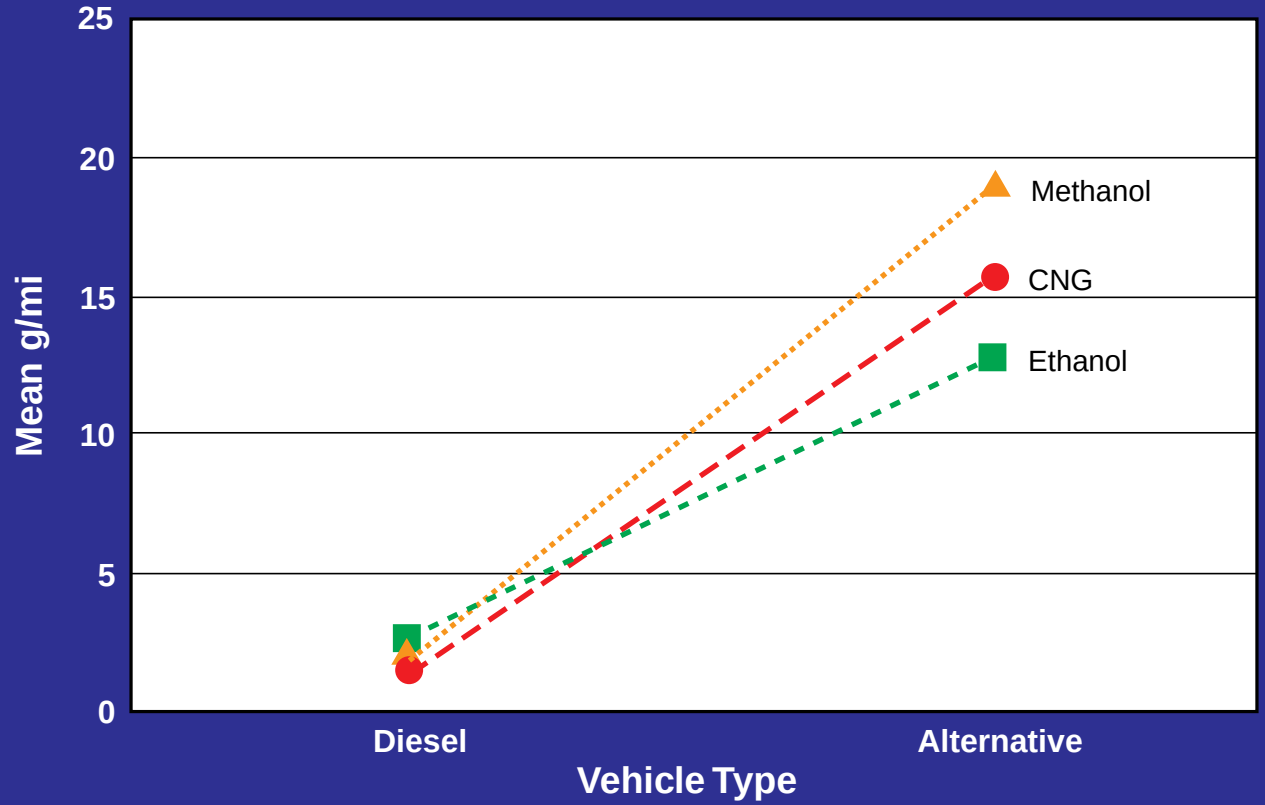


Detroit Diesel

Detroit Diesel

Cummins Engines

Hydrocarbons*



Detroit Diesel

Detroit Diesel

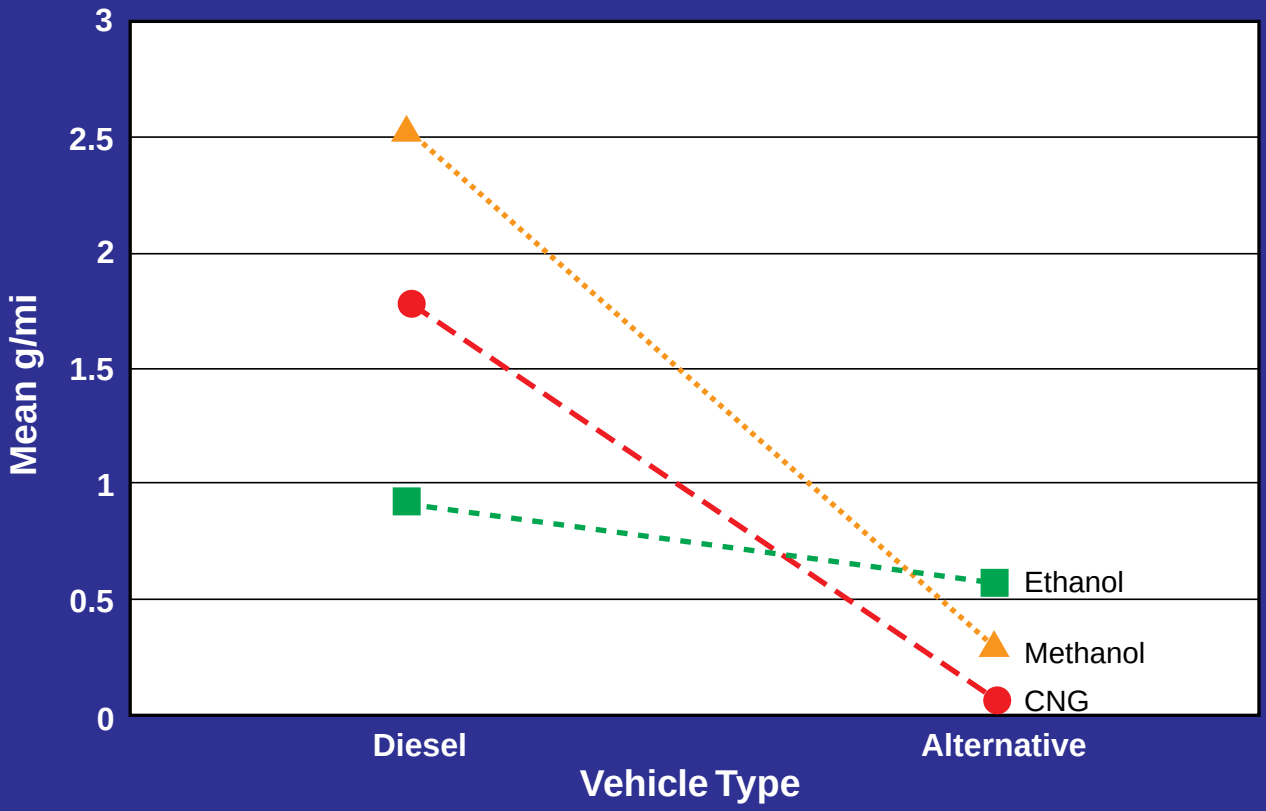
Cummins Engines

*Total Hydrocarbons;
Some engines were equipped with faulty catalysts which adversely affected emissions of hydrocarbons

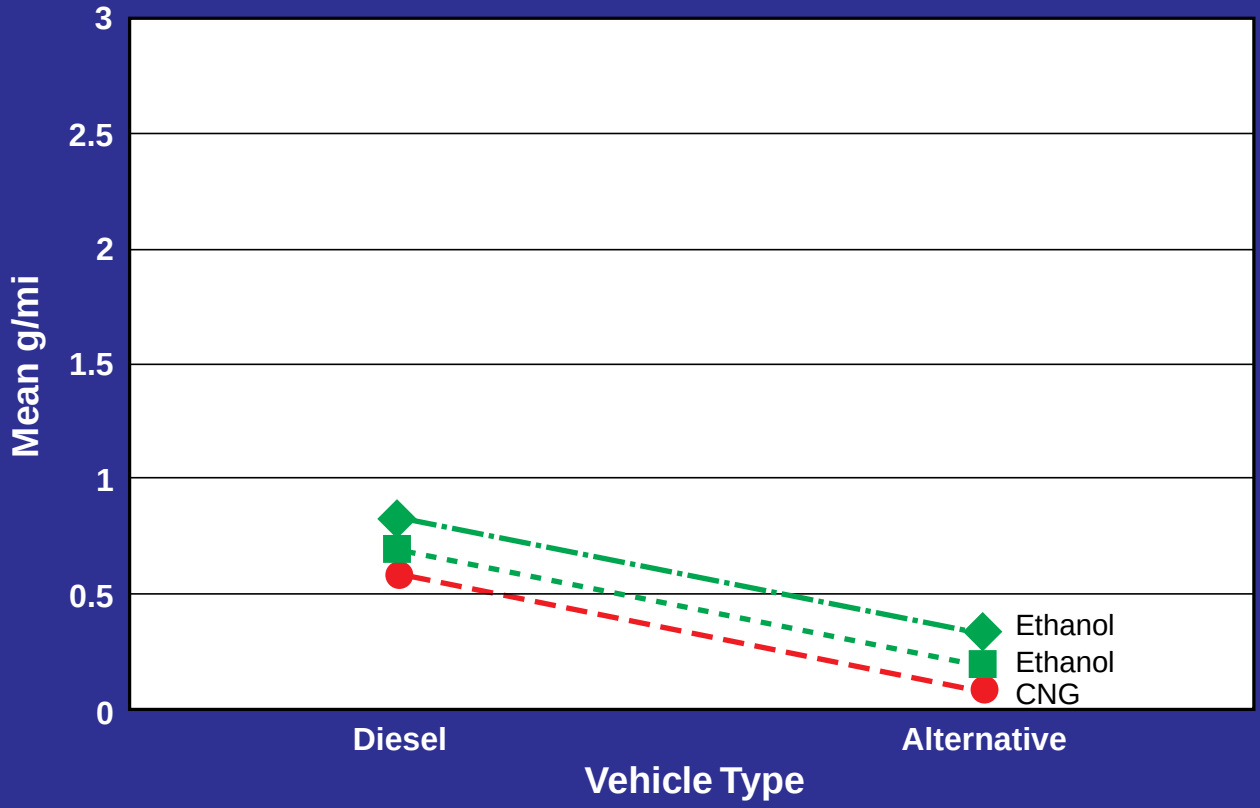
Particulate Matter:

Heavy-Duty Engines (in buses and trucks)

Particulate Matter (PM): Transit Buses (41 AFVs, 31 Controls)



Particulate Matter (PM): Heavy-Duty Trucks (12 AFVS, 5 Controls)



Snow Plows Line Haul Trucks Garbage Packers

Heavy-Duty Emissions

- Engine certification data indicates alternative fuels have the potential to reduce regulated emissions
- In-use emissions testing technology is developing
- Certification standards focus on reducing PM, without affecting NO_X
- Alternative fuel engine technology is developing; careful ongoing maintenance and repair is important to emissions performance
- Early results indicate substantial reductions in PM; levels of other emissions constituents not yet as low as desired
- R&D efforts are continuing

Conclusions and Implications

- AFVs have improved overall emissions profiles relative to conventionally-fueled vehicles (regulated exhaust emissions, toxic emissions, particulate matter, ozone forming potential)
- These findings corroborate results from other studies, but carry more weight because of the extensiveness of the testing program.
- In addition, medical investigations indicate that automotive emissions associated with alternative fuels are generally less toxic than those associated with gasoline and diesel
- So far, reductions in emissions constituents attributable to alternative fuels are most wide-ranging for sedans and other light-duty vehicles, but heavy-duty vehicles are showing great promise
- This result is important because of the sheer numbers of these types of vehicles on the road.
- Extensive deployment of AFVs would enable communities to realize improvements in public health and associated economic benefits
- Work is continuing to quantifiably establish these links

Suggested Reading

Böhm, G. M., E. Massad, P. H. Saldiva, M. A. Gouveia, C. A. Pasqualucci, L. M. N. Cardoso, M. P. R. Caldeira, and D. F. Calheiros. Comparative toxicity of alcohol and gasoline fueled automobile exhaust fumes, in Development in Science and Practice of Toxicology (A. N. Nayes, R. C. Schnell, and T. S. Miya (Eds.). Amsterdam: Elsevier, pp. 479-482, 1983.

Comparison of relative environmental impacts of alternative and conventional motor fuels. Final report, Annex VII, International Energy Agency, IEA Alternative Motor Fuels Agreement, pp. 99-108, 1995.

Egebäck, K. E. and B. M. Bertilsson, Chemical and biological characterization of exhaust emissions from vehicles fueled with gasoline, alcohol, LPG and diesel. Solna, Statens naturvårdsverk (SNV PM 1635), 1983.

Gouveia, M. A., C. A. G. Pasqualucci, P. H. Saldiva, and G. M. Böhm. Pathological aspects of intoxication by ethanol car exhaust emission. Journal of Pathology, Vol. 142, A9, 1984.

Kelly, Kenneth J., Brent K. Bailey, Timothy C. Coburn, Wendy Clark, and Peter Lissiuk, Federal test procedure emissions test results from ethanol variable-fuel vehicle Chevrolet Luminas. Society of Automotive Engineers, 1996.

Kelly, Kenneth J., Brent K. Bailey, Timothy C. Coburn, Wendy Clark, Leslie Eudy, and Peter Lissiuk, FTP emissions test results from flexible-fuel methanol Dodge Spirits and Ford Econoline vans. Society of Automotive Engineers, 1996.

Kelly, Kenneth J., Brent K. Bailey, Timothy C. Coburn, Leslie Eudy, and Peter Lissiuk, Round 1 emissions test results from compressed natural gas vans and gasoline controls operating in the U. S. Federal fleet. Society of Automotive Engineers, 1996

Lewtas, J. Impact of fuel choice on comparative cancer risk of emissions. Energy and Fuels, Vol. 7, pp. 4-6, 1993.

MacFarland, H. N., C. E. Holdsworth, J. A. MacGregor, R. W. Call, and M. L. Kane, Eds. Applied Toxicology of Petroleum Hydrocarbons. Princeton, N. J.: Princeton Scientific Publishers, Inc., 1984.

Maejima, K., T. Suzuki, H. Numata, A. Maekawa, S. Nagase, and N. Ishinishi, Toxicity to rats of methanol-fueled engine exhaust inhaled continuously for 28 days. Journal of Toxicology and Environmental Health, Vol. 37, pp. 293-312, 1992.

Maejima, K., T. Suzuki, H. Numata, A. Maekawa, S. Nagase, and N. Ishinishi, Recovery from changes in the blood and nasal cavity and/or lungs of rats caused by exposure to methanol-fueled engine exhaust. Journal of Toxicology and Environmental Health, Vol. 39, pp. 323-340, 1993.

Marnett, Lawrence J., Health effects of aldehydes and alcohols in mobile source emissions, in Air Pollution, The Automobile, and Public Health (Ann Y. Watson, Richard R. Bates, and Donald Kennedy, Eds.). Washington, D. C.: National Academy Press, pp. 579-603.

Massad, Eduardo, Carmen Diva Saldiva, Luiza Maria Nunes Cardoso, Ruberval Da Silva, Paulo Hilário Nascimento Saldiva,and Gyorgy M. Böhm. Acute toxicity of gasoline ethanol automobile engine exhaust gases. Toxicology Letters, Vol. 26, pp. 187-192, 1985.

Speizer, F. E. and B. G. Ferris, Jr., Exposure to automobile exhaust. II.Pulmonary function measurement. Archives of Environmental Health, Vol. 26, pp. 319-324, 1973.

Timourian, H. and F. Milanovich, Methanol as a transportation fuel: assessment of environmental and health research. Unpublished report UCRL-52697, Lawrence Livermore National Lab, pp. 35-60, 1979.

Watson, Ann Y., Richard R. Bates, and Donald Kennedy, Eds. Air Pollution, The Automobile, and Public Health. Washington, D. C.: National Academy Press, 1988.